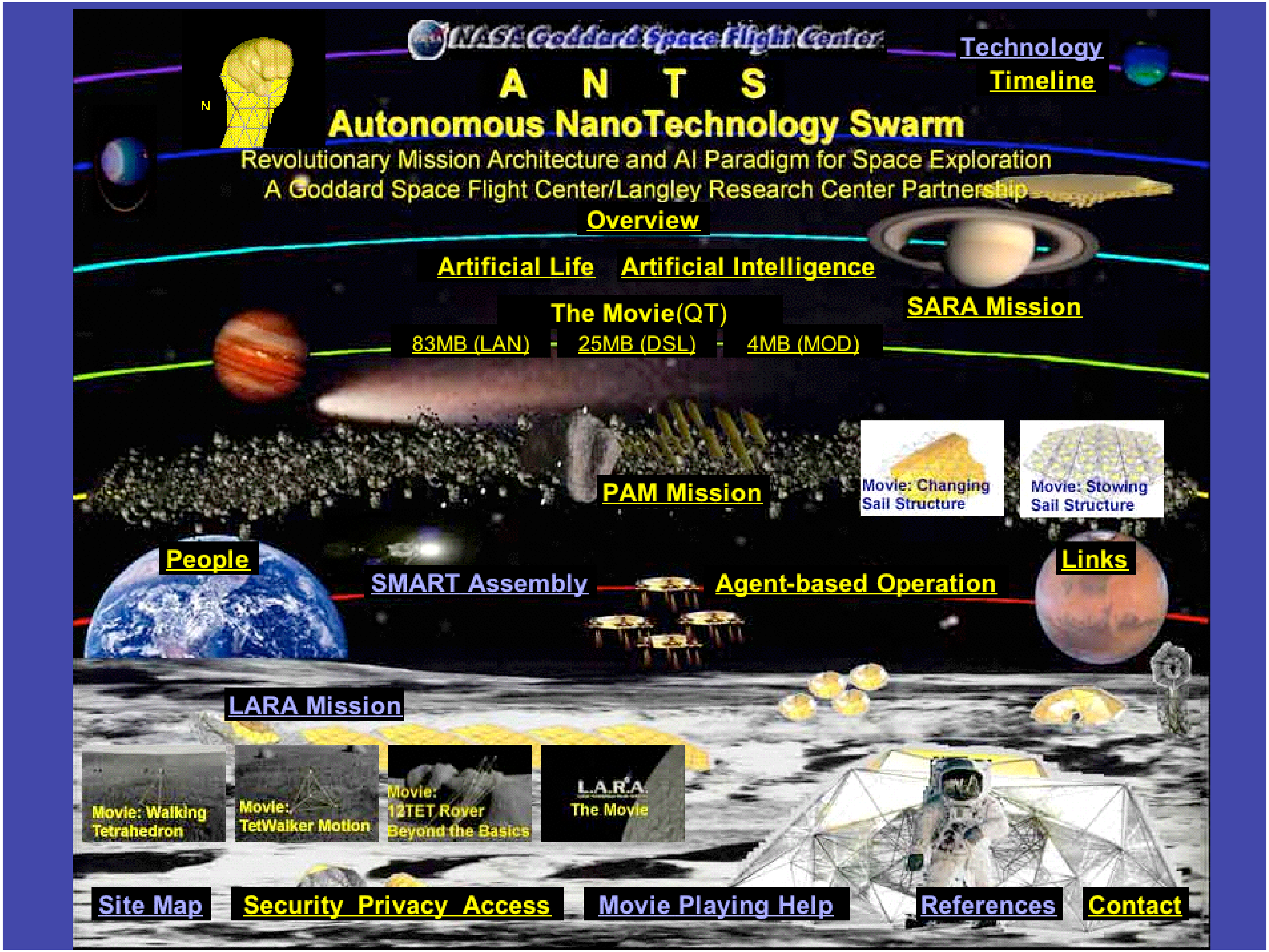
ANTS: Autonomous NanoTechnology Swarm

An architecture for autonomous missions with the following characteristics:

1) An addressable, reconfigurable, self-configuring, networked swarm
2) Nodes (synthetic nervous system) which reversibly deploy struts and shells (synthetic skeletal muscular framework and skin), allowing transformation in form and thus function.
3) Hierarchical (multi-level, dense heterarchy) organization.
4) Bilevel intelligence for autonomic (lower level) and heuristic (higher level) functions.
5) Undifferentiated components which can be specialized to achieve optimal performance for the range of mission activities.


NASA Goddard Space Flight Center
Technology
Timeline
A N T S
Autonomous NanoTechnology Swarm
Revolutionary Mission Architecture and AI Paradigm for Space Exploration
A Goddard Space Flight Center/Langley Research Center Partnership
Overview
Artificial Life
Artificial Intelligence
SARA Mission
The Movie(QT)
83MB (LAN)
25MB (DSL)
4MB (MOD)
PAM Mission
Movie: Changing Sail Structure
Movie: Stowing Sail Structure
People
SMART Assembly
Agent-based Operation
Links
LARA Mission
Movie: Walking Tetrahedron
Movie: TetWalker Motion
Movie: 12TET Rover Beyond the Basics
L.A.R.A. The Movie
Site Map
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References
Contact

Intelligent Systems in the Evolvable ANTS Architecture

ants.gsfc.nasa.gov

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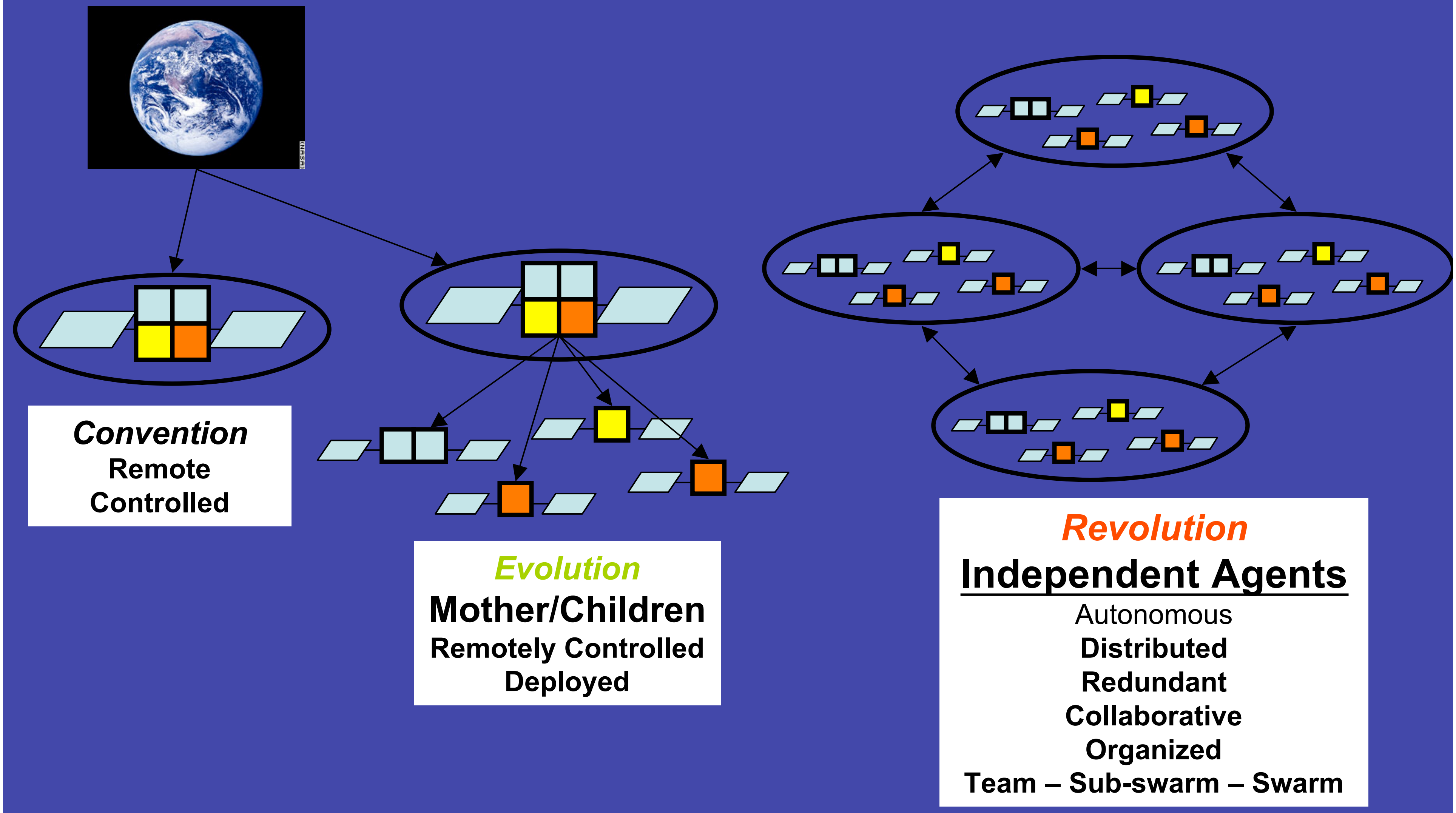
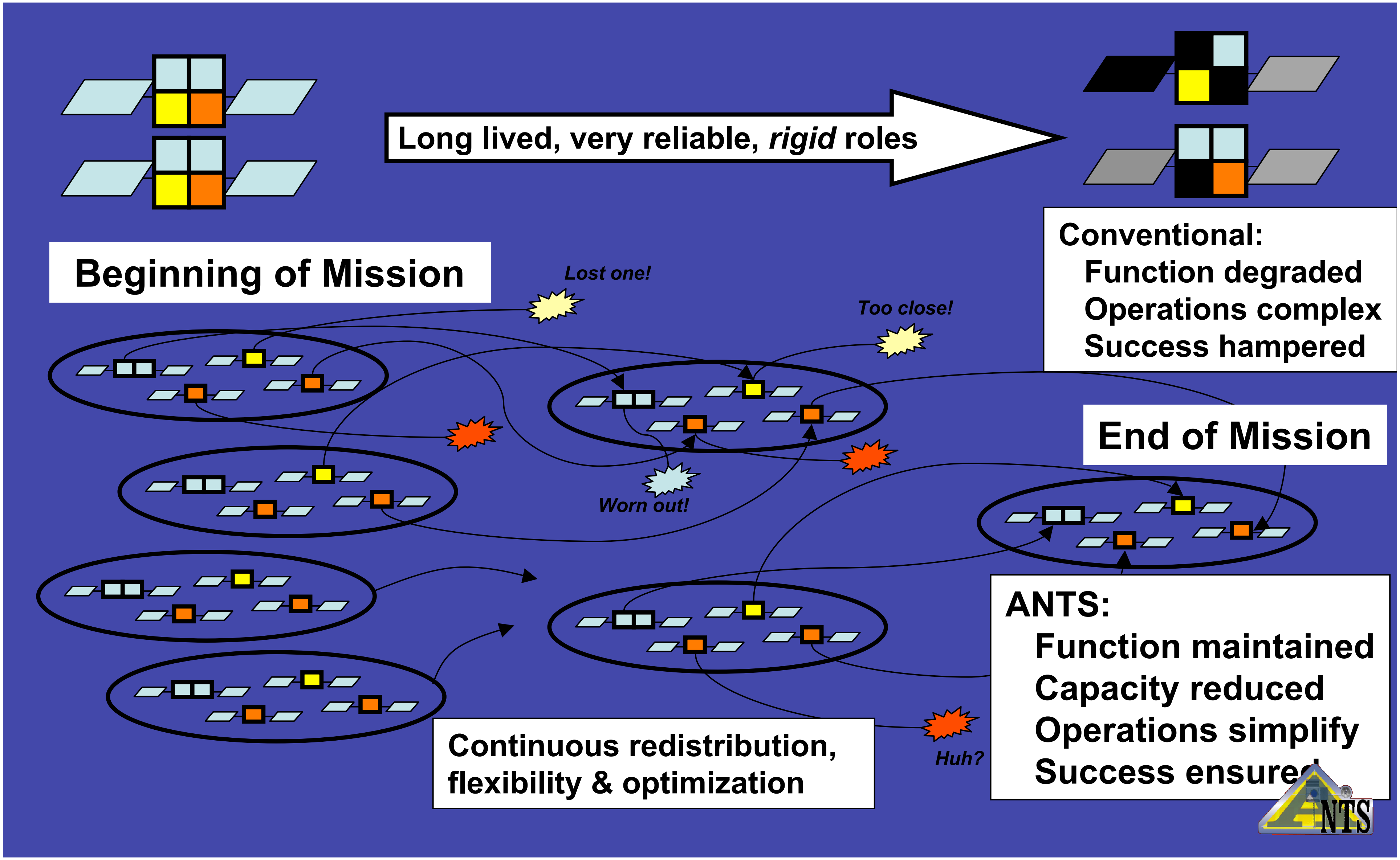
SWARM: Convention, Evolution, *Revolution*

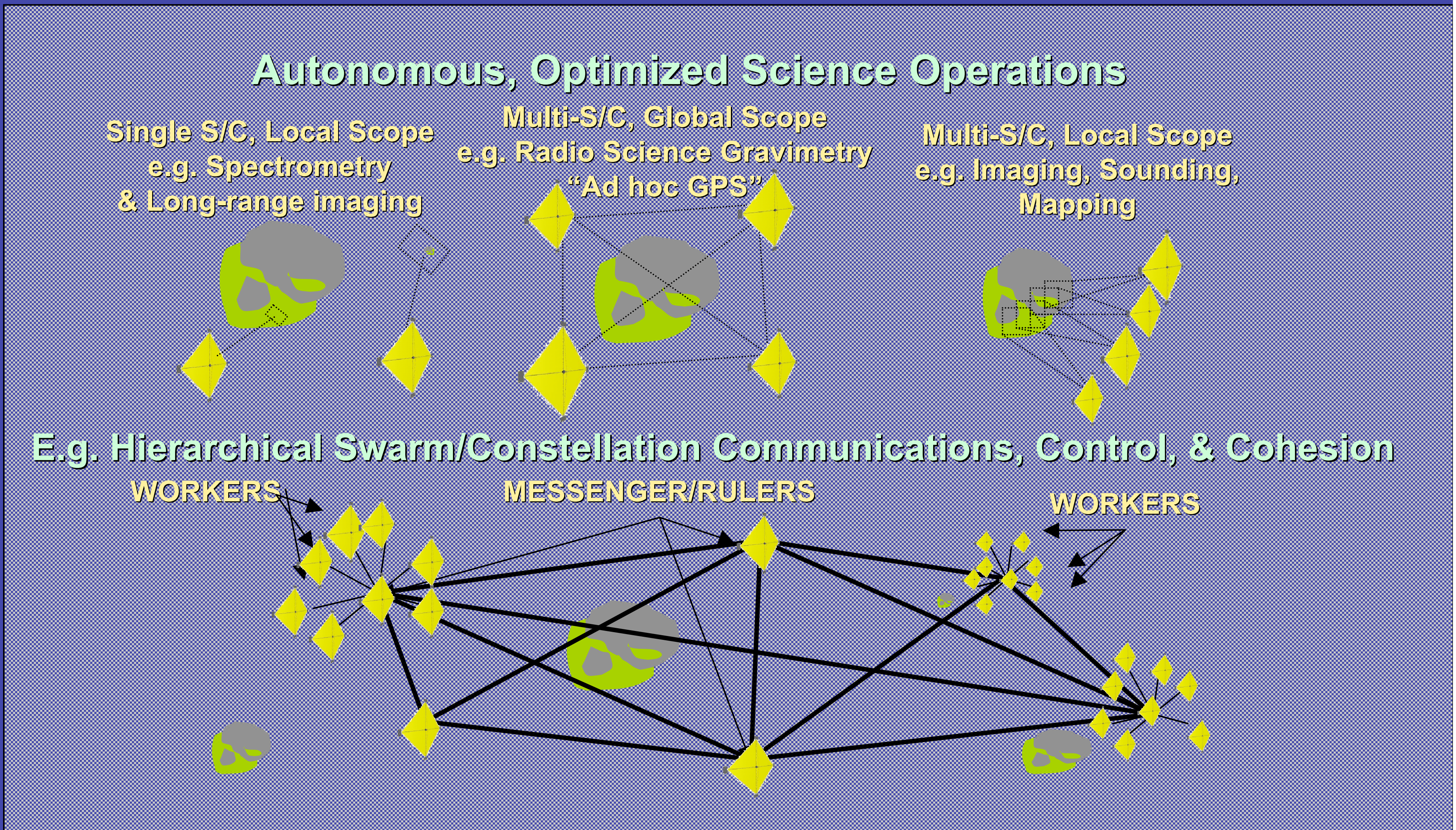


SWARM: Contrasting *centralized* vs. *distributed*

Autonomous agents with *organizational plasticity* maintain functions.



SWARM Organization, Local, Global, Hierarchical



Evolvable ANTS Architecture

- Multi-Level Reconfigurability
  - System Level
    - Swarm Reconfiguration and Reallocation
    - Multi-agent Collaboration
  - Subsystem Level
    - Functional Adaptation
  - Module Level
    - Evolvable Functions
- Evolvable Hardware
  - Segmented Gossamer Space Frame

The Role of Intelligent Systems

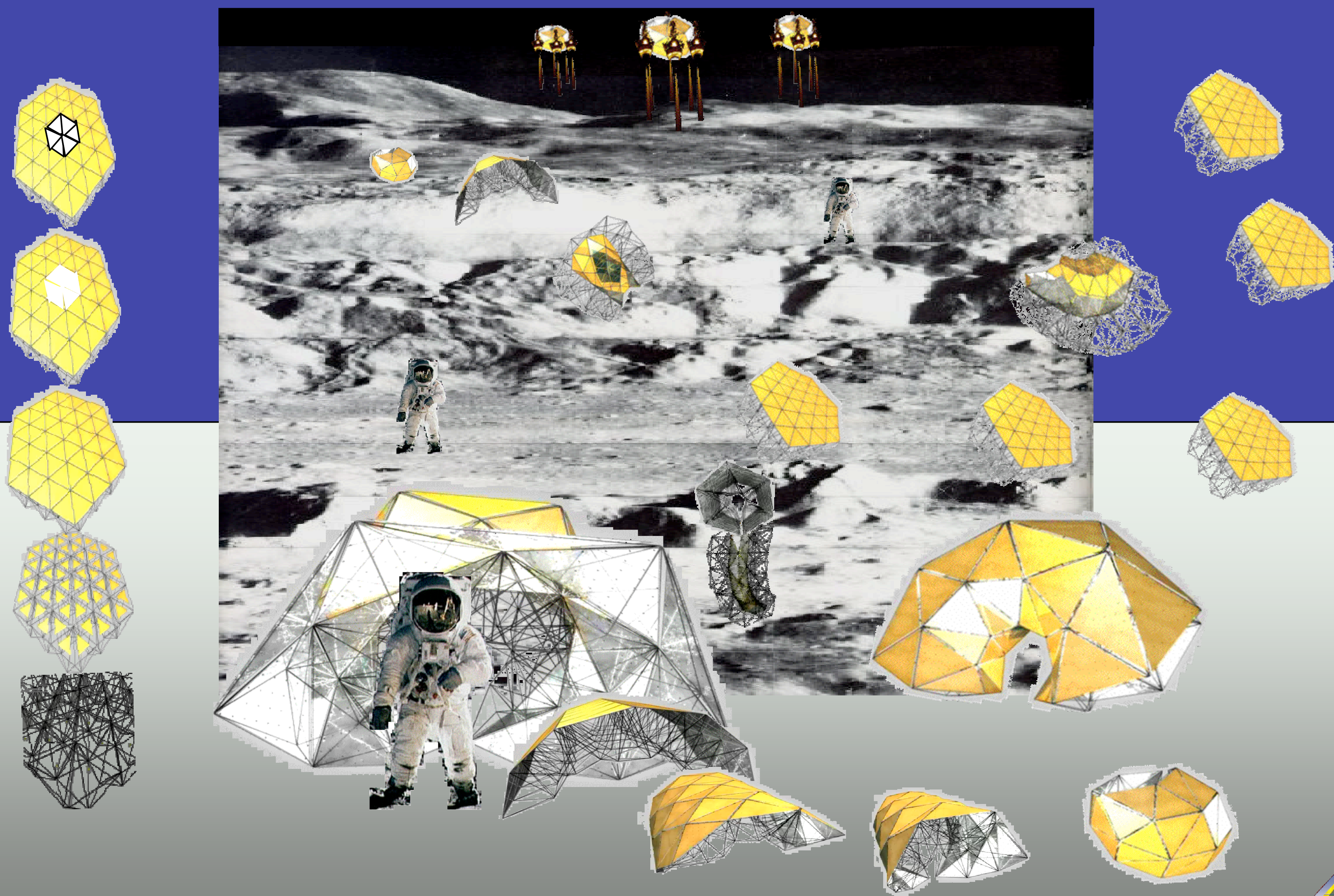
- Heuristic Level
  - Planning & scheduling
  - Mission goal monitoring
  - Science prioritization
  - Multi-agent collaboration
- Autonomic Level
  - Attitude control
  - Target tracking
  - Sensor-actuation control

ANTS Synthetic Neural System (SNS)

Exploring the meaning of autonomy

- Recognition of high (heuristic) and low (autonomic) level requirement - *bi-level intelligence*
  - software constructs for both levels and interconnection
  - neural basis function design
  - a lumped approach based on applied math
  - 3D complexity and neural self-similarity as enabling
- Adaptable and evolvable with core genetic code
  - trainable to avoid initialization and specification problems
  - avoids medieval homunculus problem
  - allows embryonic development

Multi-functional Structures for Exploration
Lunar Amorphous Rover Antenna (LARA)



Self Repair of Gossamer Space Frame

1) Response to injury robust through compensatory behavior:

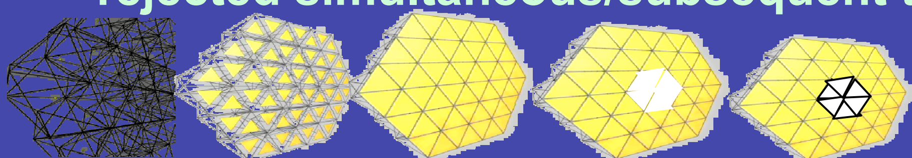
2) Segmented design localizes injury

3) Synthetic neural system evolutionary/adaptive capability to 'limp'

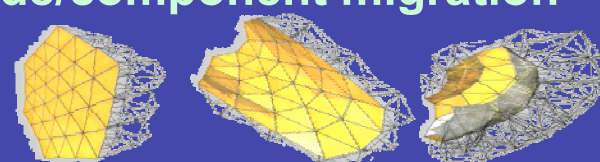
4) Local healing: tetrahedral structure stretches to fill damage area

5) Regional repair: extension of manufacturing process

- node/component migration to damage site either from stored parts or less critical areas
- strut retraction around damage site
- migration via strut progressive attachment/detachment as node climbs to repair site
- good nodes around damage area release and damage area rejected simultaneous/subsequent to node/component migration



Self-deployment of struts and surfaces from nodes to form or repair structure as required



Self-configuration to form or repair morphology as required

Processing Power for Space Missions

Year	CPU	MIPS/Watt
1990	NSSC-1 on GRO	< 1
1995	80386 on XTE	~ 2
2001	MIPS R3000 on EO-1/MAP	~ 10
2004	Rad600 on MER (Spirit / Opportunity)	35
2007	ColdFire 3.3 volt on GPM and SDO	37
2011	Power PC on JWST	85

In-space Intelligent Systems

Possible approaches for high-performance computing:

A. Hardware

- Beowulf in space
  - Combine multiple von-Neumann processors into a distributed memory parallel computer
- Application Specific Integrated Circuit (ASIC)
- Reconfigurable processors
  - Field Programmable Gate Arrays (FPGA)
  - Field Programmable Processor Arrays (FPPA)
    - Non Van Neuman architecture

B. Software

- Efficient algorithms with lower computational cost
- Algorithms most suited for specific computer architecture

ST-8

- JPL-led Beowulf in space project
- Developing science application software for testbed
- Possible flight test ~2007

Issues:

Mass, power, thermal control, radiation susceptibility

Field Programmable Processor Array

- Reconfigurable data path
  - Programmable at run-time
- Ultra low power
- Radiation hardened by design
- Non von-Neumann architecture
- Most suitable for autonomous control tasks and science applications with large data flow

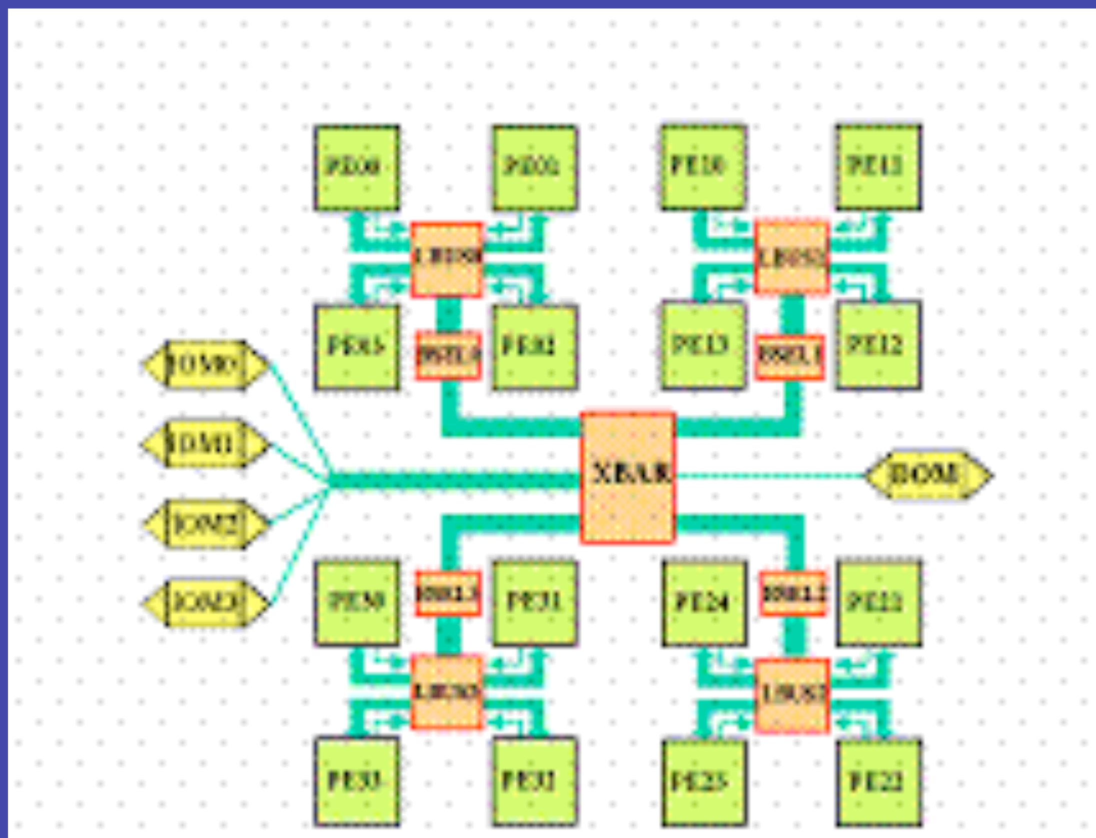
Current Applications:

- Fast Fourier Transform
- Sensor readout correction

Future Application: IS algorithms

FPPA

Interconnected Processing Elements via a crossbar based network.



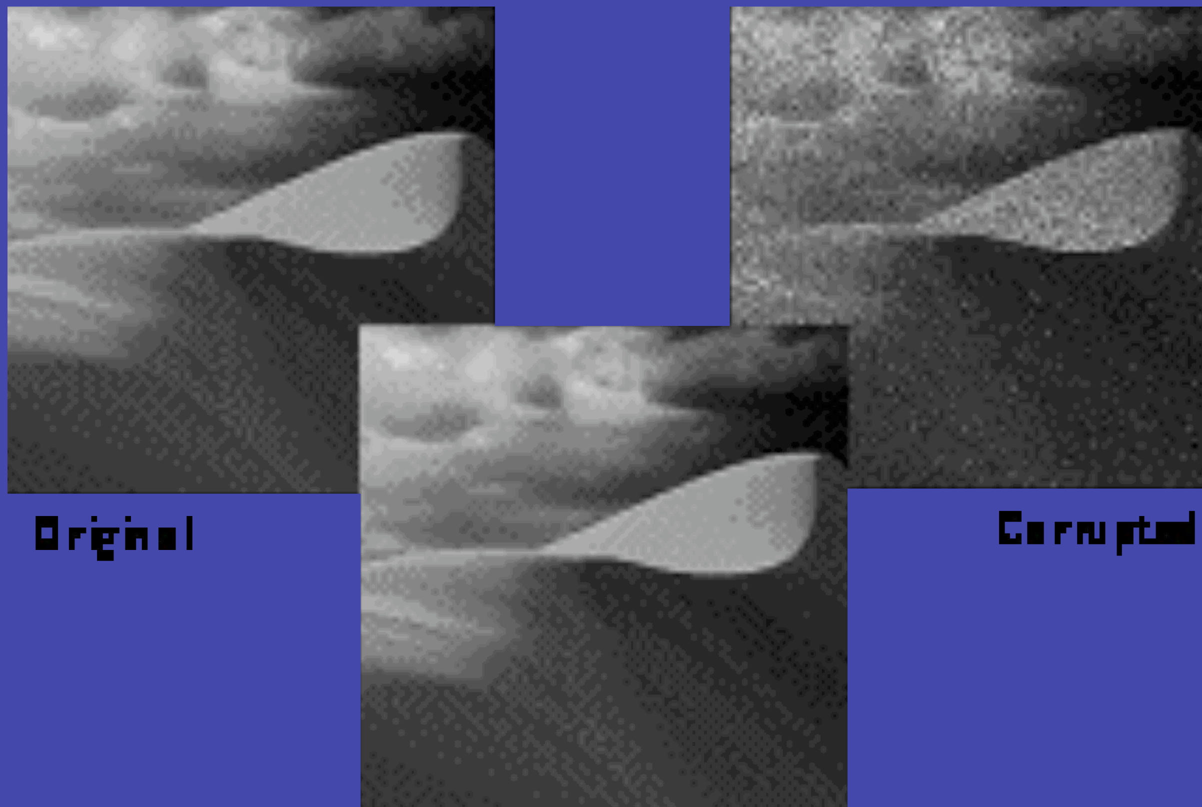
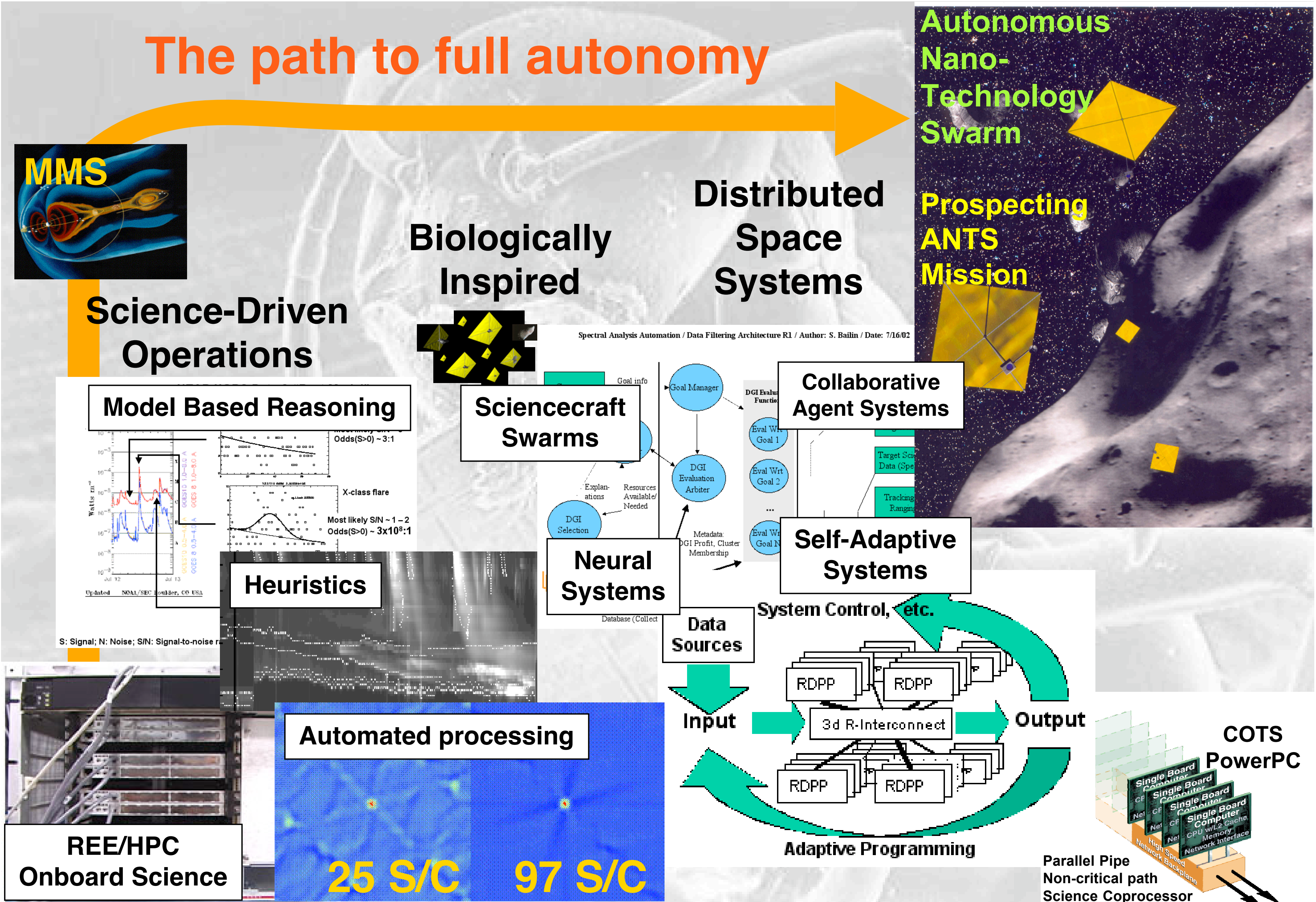


Figure 2.6 Sensor Readout Correction on FPPA Simulated in Software



Onboard Supercomputing & Advanced Hardware/Software Architectures

S. Curtis, C. Cheung NASA/GSFC; M. Rilee L-3/EER; 5/1/2003. Ant microphoto, Huddersfield University (Reuters, 1999)